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Exogeneity of the circaseptan mood rhythm and its relation to the working week

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Previous longitudinal studies of mood showed that mood displays a circaseptan (weekly) rhythm, reaching its peaks during weekends and falling during the working week. These studies stirred numerous debates about whether the circaseptan nature of the mood is determined culturally or biologically. The goal of the present study was to determine how the division of the week on the working week and the weekend impacts mood. A sample of students completed the shortened version of the PANAS-X questionnaire each day throughout July (working week and the weekend not separated) and November (working week and the weekend separated). Cosinor rhythmometry was used to analyze the data. As in previous research, a circaseptan mood rhythm was detected in November. However, a circaseptan rhythm was not detected in July - a circasemilunar rhythm was detected instead. These results suggest that the division of the week on the working week and the weekend has a great impact on mood and that more longitudinal studies of this type are needed to better understand this relationship.

Key words: circaseptan, mood, PANAS, weekend, working week

Many physiological and psychological processes follow a certain biological rhythm. Sleep patterns (Dijk & Lockley, 2002) and temperature (Refinetti & Menaker, 1992), among many others, follow a circadian rhythm. Menstrual cycle (Farage, Neill, & MacLean, 2009) and food and alcohol intake (De Castro & Pearcey, 1995), for example, follow a circalunar rhythm, while testosterone levels in men (Smals, Kloppenborg, & Benraad, 1976) and DNA synthesis in certain tissues (Sothern, Smaaland, & Moore, 1995) follow a circannual rhythm.

Mood is an affective phenomenon that is distinct from emotions in several characteristics. Apart from being less intensive, mood was also found to be of longer duration than emotions (Beedie, Terry, & Lane, 2005). In fact, mood is a constant state that can vary in quality and intensity, but can never disappear. A considerable number of longitudinal mood studies have been conducted to investigate how mood varies in time. Results from those studies suggest that mood varies in a circaseptan (weekly) fashion (Cornélissen et al., 2005; Larsen & Kasimatis, 1990). More specifically, mood tends to increase on weekends and decrease as the working week starts. The intensity of mood remains relatively stable during the working week and rises again when a new weekend starts.

This cause of circaseptan variation of mood is not yet explained. Two opposing viewpoints address this question (Larsen & Kasimatis, 1990). The biological viewpoint holds that the mood variation is determined primarily by biochemical processes in the body. Many non-psychological processes in the human body have been found to adhere to a circaseptan rhythm. Larsen and Kasimatis (1990) list a few: concentration of certain chemicals in the urine (Halberg, 1983), erythrocyte count and hemoglobin concentration (Haus, Lakatua, Swoyer, & Sackett-Lundeen, 1983), certain functions of the immune system (Campbell, 1986), properties of certain diseases (e.g., breast cancer temperature; Halberg, 1983). Circaseptan rhythms were also observed in animals (Uezono, Sackett-Lundeen, Kawasaki, Omae, & Haus, 1987). Since it is known that affective phenomena have their biological underpinnings in the form of certain chemical substances in the body, namely neurotransmitters (Lövheim, 2012), the circaseptan variation of mood could be a result of possible circaseptan variation of those biochemical substances. Proponents of the biological viewpoint argue that circaseptan variations are innate (Halberg, 1983) and that their function is to coordinate cooperation between various body systems (Hildebrandt & Geyer, 1984).

On the other hand, the cultural viewpoint considers that the mood variation is determined primarily by social factors. Researchers favoring the cultural viewpoint typically

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argue that most societies developed a 7-day week because of market economy (Zerubavel, 1985). Since early societies had no preservatives for food, they had to construct an arbitrary time period, which allowed for the optimal relationship of supply, demand, and product quality, which decreased quickly due to lack of preservatives. Coincidentally, such a period turned out to last seven days. Supporters of the cultural viewpoint argue that the circaseptan mood variations are not innate. Instead, they are determined by the elevation of mood on weekends, when people do not have to work. According to these theorists, the existence of circaseptan rhythms in non-psychological variables does not prove that those rhythms are innate; it simply means that the stress caused by work affects other body systems and alters their natural rhythm. Circaseptan rhythms observed in animals could be spontaneously and unknowingly induced by behavior of scientists observing these animals, since the behavior of scientists likely differs during the working week and the weekend (Larsen & Kasimatis, 1990).

Due to a lack of research and evidence that would give favor to any of the two viewpoints, the debate about the origin of circaseptan rhythms remained theoretical. The lack of empirical data on this topic is partly a result of the fact that the conventional paradigm for researching biological rhythms could not have been applied in this case. In traditional studies of biological rhythms, participants are isolated from the so-called *zeitgebers* – environmental events which synchronize the rhythm. This allows researchers to investigate the so-called *free-running* rhythms. Aschoff and Wever (1962) studied circadian rhythms of sleep and wakefulness. In this study, participants were living in a bunker, which isolated them from sunlight, moonlight, and other environmental signs they could use to know the time of the day (zeitgebers). The results of the study showed that, even in the absence of zeitgebers, the cyclic alteration of sleep and wakefulness follows a circadian rhythm and lasts 25–27 hours. Since there were no events in the bunker, which could synchronize the rhythm to that duration – in other words, the rhythm was free-running, these results suggest that the circadian rhythm of sleep and wakefulness is biologically innate. Such a rhythm probably evolved during the course of evolutionary history for adaptive purposes. If it were not for that rhythm, many humans could display nocturnal instead of diurnal behavior, which would probably be maladaptive in the prehistoric environment.

The situation with circaseptan rhythms is somewhat more complicated. Except for the schedule of the recurring obligations, there are no external signs that would mark the passing of one week. Certain theories argued that the lunar phases mark the passing of the week. However, these hypotheses are not fully justified because the cyclicity of zeitgebers should coincide with the cyclicity of the rhythm. For example, the beginning of the day is marked by the sunrise. As the day progresses, the sunset occurs and the moon rises. At the end of the night, the moon sets and the sun rises again. Each day begins and ends with the same events. Human sleep patterns coincide with these events. However, if a hypothetical week began with the new moon, as the week passes by, the moon would gradually evolve to its first quarter phase and the next week will begin with the moon in first quarter. The third week will start with the full moon, the fourth with the last quarter etc. Thus, the beginning and the end of each week are marked by different instead of same lunar phases, meaning that the lunar phases are not a good candidate for a zeitgeber of circaseptan rhythms. There are no known naturally occurring events which undergo a cyclical repeat pattern throughout a week. Therefore, it is unclear how the circaseptan rhythms could have evolved throughout the human evolutionary history.

Another problem that arises in studying circaseptan rhythms in humans is that it is hardly possible to isolate participants from the zeitgeber – the obligation schedule – which synchronizes the circaseptan rhythm. This problem could be reduced by performing extensive studies like the Aschoff and Wever's (1962) study of circadian rhythms. However, most researchers lack the financial funds required to conduct such a study. More importantly, not even an extensive study, like Aschoff and Wever's (1962) study of circadian rhythms, would fully eliminate this problem. While it was difficult for participants of Aschoff and Wever's (1962) study to tell the current time in the dark cave, even if they had no obligations, they could easily tell the day of the week by counting how many times they have slept. This prevents the use of the isolation paradigm and makes it difficult for the researchers to study a free-running mood rhythm. However, a replacement for the isolation paradigm can be found instead. In Western culture, the week is typically divided on the working week (Monday through Friday) and the weekend (Saturday and Sunday), which is considered by the cultural theorists to be a cause of the circaseptan variation of mood. However, there are certain periods of the year when people are free from their obligations. In such periods, the difference between the working week and the weekend is not so clear since people do not attend to their obligations neither during the working week nor during the weekend. Mood rhythms can then be studied during such periods when the week is 'unstructured' and the results can be compared to the periods when the week is 'structured' (i.e., when the distinction between the working week and the weekend is clear). This is a satisfactory replacement for the isolation paradigm since the zeitgebers, which according to the cultural theorists synchronize the circaseptan rhythm, i.e., obligations, are gone and free-running mood rhythms can be investigated. Indeed, it is not uncommon to hear students complaining during summer months that they do not know which day of the week it is. Therefore, if the viewpoint of the biological theorists is true, the circaseptan mood rhythm should be detected both during the structured and unstructured weeks, and if the viewpoint of the cultural theorists is true, the circaseptan mood rhythm should only be detected during structured weeks.

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The aim of this study was to determine the impact of the structure of the week on the mood. More specifically, the aim was to determine does the division of the week on the working week and the weekend have an impact on the appearance of the circaseptan mood rhythm. Based on the literature, two opposing hypotheses can be formulated to predict the results:

Biological hypothesis. A significant 7-day sinusoidal rhythm of responses on the PANAS questionnaire will be detected both in July and November.

Cultural hypothesis. A significant 7-day sinusoidal rhythm of responses on the PANAS questionnaire will be detected in November, but no significant sinusoidal rhythm will be detected in July.

METHOD

Participants

The sample in this research consisted of 47 participants (36 female), most of them undergraduate psychology students at the University of Zagreb (M_{age} = 20.46, range 19–24 years). The analyses were performed including only participants who responded in more than 85% of cases each month. Thus the number of participants was 27 in July and 21 in November. Students applied for participation via an online form. Students earned credits for participation and were also encouraged to ask their colleagues (non-psychology students) to participate to earn extra credits. Participation in this research was anonymous – each participant was randomly assigned an online generated five-letter secret code, which they used throughout the experiment. In order to earn the credits, participants were required to respond on at least 90% of days. The average number of daily responses was 33 in July and 28 in November.

Measures

A shortened form of PANAS, previously used by Križanić (2013) on a Croatian sample, was chosen for this research. The questionnaire consisted of 16 items (interested, distressed, excited, upset, scared, enthusiastic, irritable, inspired, nervous, determined, cheerful, lonely, angry, relaxed, happy, sad) taken from PANAS-X (Waston & Clark, 1994). Eight items were indicators of positive affect and eight of negative affect. Križanić (2013) selected the items due to them having the best psychometric properties after adaptation of PANAS-X to Croatian language. For each of the 16 items, participants had to indicate to what extent they felt like that during the current day on a scale from 1 to 7. A linear combination was formed for positive and negative affect separately and total score was calculated as the difference between the positive and negative affect.

In addition to filling out the shortened form of PANAS, participants were also required to answer whether or not they had participated in the following activities that day: studying, working or volunteering, going out or planning to go out (e.g., to clubs and birthday parties), attending classes at the University (only during the November cycle), completing university-related assignments excluding studying and participating in this research (only during the November cycle). They were also required to state whether or not they experienced a significant life event on that day, and if that event was positive or negative. This data had been collected to confirm that the disparity between the working week and the weekend does not exist in July, but does exist in November, and to explore other possible sources of mood variation.

Procedure

The research consisted of two cycles, one in July and one in November. These months were chosen because July is a summer month with no daily recurring university obligations and November is a typical "working" month (most of the classes started in mid-October). Thus, we can expect that the disparity between the working week and the weekend does not exist (or is less pronounced) in July, but exists in November. It is possible that students are not obligation-free in July and are working instead, since they have more time to work due to absence of university obligations. However, many student jobs also require work during the weekends (waitering, working in call centers, working in retail, etc.). Therefore, student jobs should not impact the non-existence of a clear boundary between the working week and the weekend in July.

Participants filled out the questionnaire online via Google Forms service every day. Order of the PANAS items was randomized every day for every participant. The questionnaire was accessible only from 8 p.m. to midnight each day to ensure that participants filled out the questionnaire only when most of the day had passed. Participants who were prevented from filling out the questionnaire by this restriction due to them not being in the central European time zone on that day, were redirected to a special form where they, in addition to filling out the "standard" questionnaire, also had to report the local date and time in the time zone in which they were currently situated to confirm that they were responding in the allowed time period. E-mail reminders were scheduled to be automatically sent to all participants every day at 6 p.m.

Data analysis

Cosinor rhythmometry (Cornélissen, 2014) was used to analyze the population-mean mood rhythms. Cosinor is a statistical technique which utilizes the least-squares method to find a sinusoidal curve which best fits a set of longitudinal data. The general equation of a sinusoide estimated by the cosinor model is:

$$Y = M + A\cos\left(\frac{2\pi t}{\tau} + \varphi\right) \quad (1)$$

where Y is the predicted value of the rhythm at the time t; M is the MESOR (Midline Estimating Statistic of Rhythm), a measure of the average value of the measured rhythm; A is the amplitude, the measure of difference between the average value of the rhythm and the rhythm's minimum or maximum; t is the time at which the measurement was taken; τ is the period, a measure of the number of measurement points between the two points in which the rhythm achieves its maximum or minimum; and φ is the acrophase, the distance between the first measurement point and the point in which the rhythm achieves its maximum, expressed in degrees or radians.

Cosinor can be extended in several ways to facilitate rhythmometrical analyses. An iterative cosinor procedure (Klemfuss & Clopton, 1993) can be used to construct a periodogram to find the best fitting period, τ, for the model. Serial sections (Arbogast, Lubanovic, Halberg, Cornélissen, & Bingham, 1983; Cornélissen, 2014) can trace the variations of MESOR, amplitude, and acrophase over time in non-stationary cosinor models. Lastly, multicomponent cosinor models (Cornélissen, 2014) can be used to analyze rhythms which deviate from sinusoidality, but can be decomposed into several sinusoidal components.

RESULTS

Mood

Firstly, an iterative cosinor procedure was used to estimate the period of the rhythm. This analysis revealed that the best-fitting period is 12 days in July and 7 days in November (Figure 1). Cosinor rhythmometry detected a statistically significant rhythm in July with the period of 12 days, $F(2, 25) = 8.618$, $p = .001$ (Figure 2), and in November with the period of 7 days, $F(2, 19) = 6.486$, $p = .007$ (Figure 3).

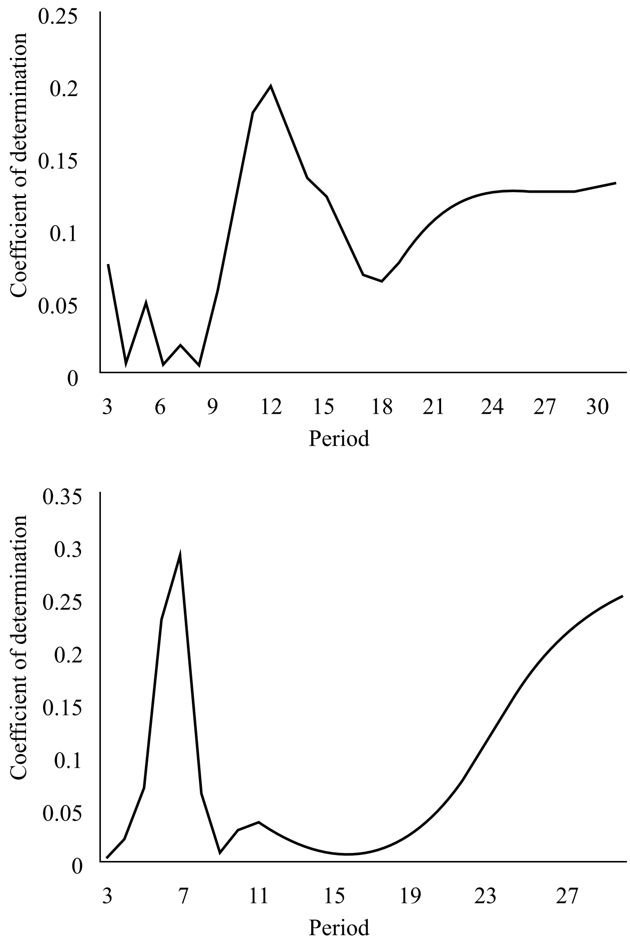

Figure 1. Periodograms for July (top chart) and November (bottom chart) showing the proportion of explained variance (coefficient of determination) by each period in iterative cosinor procedure.

Values of parameters of those rhythms are shown in Table 1. No statistically significant rhythm was detected in July with the period of 7 days, $F(2, 25) = 0.091$, $p = .913$, nor was it detected in November with the period of 12 days, $F(2, 19) = 0.384$, $p = .687$.

Table 1
Values of cosinor parameters, 95% confidence intervals and the proportion of explained variance in July and November

	July		November	
Parameter	Value	95% CI	Value	95% CI
MESOR	1.54	1.09–1.99	1.41	0.93–1.89
Amplitude	0.32	0.15–0.49	0.32	0.12–0.52
Acrophase	-265°22'38.1"	-305°11'29.7"–-214°3'51.6"	-323°49'13.4"	-362°28'36.3"–-269°53'35.7"
Coefficient of determination	.20		.30	

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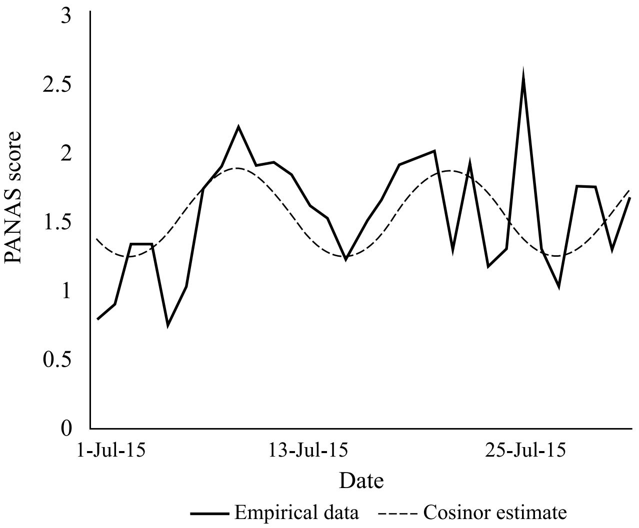

Figure 2. Empirical data and cosinor estimate of mood rhythm in July.

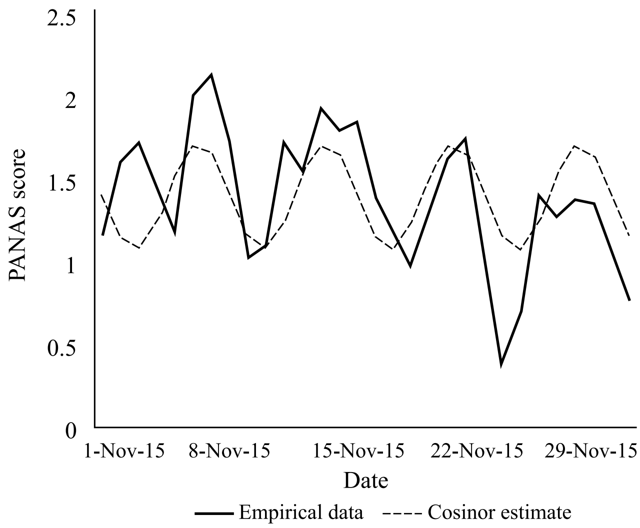

Figure 3. Empirical data and cosinor estimate of mood rhythm in November.

Since the number of participants was not equal in July and November, analyses were also performed only on 19 subjects who participated in more than 85% of cases in both months to rule out the possibility that the participants who departed from the research distorted the data. A statistically significant rhythm with the period of 12 days in July, $F(2, 17) = 4.982$, $p = .020$, and with the period of 7 days in November, $F(2, 17) = 5.204$, $p = .017$ was detected. Statistically significant rhythm of 7 days was not detected in July, $F(2, 17) = 1.253$, $p = .311$, nor was a significant rhythm with a period of 12 days detected in November, $F(2, 17) = 0.154$, $p = .858$. Since the results of analyses performed only on 19 participants and analyses performed on 27 participants in July and 21 participants in November are substantially the same, further analyses were performed on 27 and 21 participants in July and November, respectively, to increase statistical power.

Acrophases of the mood rhythm in July occurred on July 9 (Thursday) and July 21 (Tuesday) and bathyphases (timepoints at which the rhythm achieves the lowest value) occurred on July 3 (Friday), July 15 (Wednesday) and July 27 (Monday). Acrophases of the mood rhythm in November occurred on November 6, November 13, November 20 and November 27 (Fridays) and bathyphases occurred on November 3, November 10, November 17 and November 24 (Tuesdays).

To increase the proportion of explained variance, serial sections were extended to a population-mean level to trace the variations of cosinor parameters. Linear regression was used to obtain the equation of trend of each parameter and those trends were included in the cosinor model afterwards. Table 2 shows equations of trends of cosinor parameters. Using the interval lengths of 12 days in July and 7 days in November resulted in p-values larger than .05 in most intervals. Therefore, interval lengths of 24 and 14 were used, respectively. Displacement was 1 day in all cases. Serial section analysis revealed that the MESOR of mood is increasing in July and decreasing in November. Amplitude was decreasing in July and increasing in November, while acrophase was increasing in both months. Figure 4 shows serial sections output for July and November.

Table 2

Equations of trends of cosinor parameters obtained by linear regression and the proportion of explained variance in July and November

Parameter	July	November
MESOR	0.02t + 1.42	-0.03t + 1.81
Amplitude	-0.01t + 0.39	0.01t + 0.33
Acrophase	0.05t – 5.16	0.04t – 6.33
Coefficient of determination	.28	.55

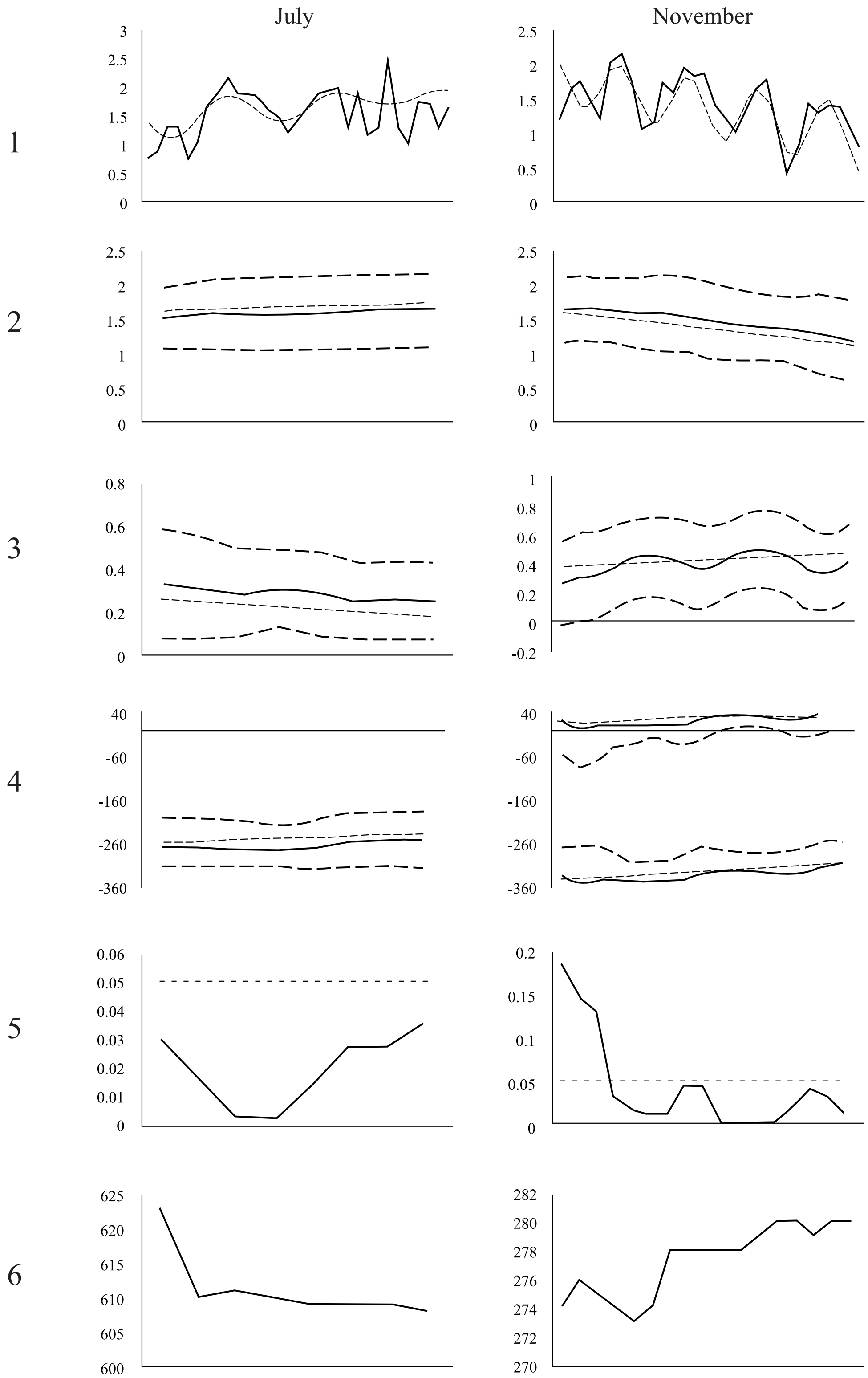

Figure 4. Serial sections for (a) July (left side) and (b) November (right side) showing from top to bottom: 1) chronogram with empirical data (continuous line) and cosinor estimate (discontinuous line), 2) MESOR, 3) amplitude and 4) acrophase (continuous line), 95% confidence limits (discontinuous thick line) and linear regression estimates (discontinuous thin line), 5) p-value (continuous line) and .05 limit (discontinuous line) and 6) number of collected answers per interval across intervals. Legends and text on charts were omitted due to insufficient space.

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Daily activities, positive and negative events

Since participation in each of the daily activities monitored in this study and experiencing positive and negative events are binary variables, conventional procedures for detecting rhythmicity could not have been used. Instead, a percentage of participants taking part in the activity or experiencing a positive or negative event was calculated for each

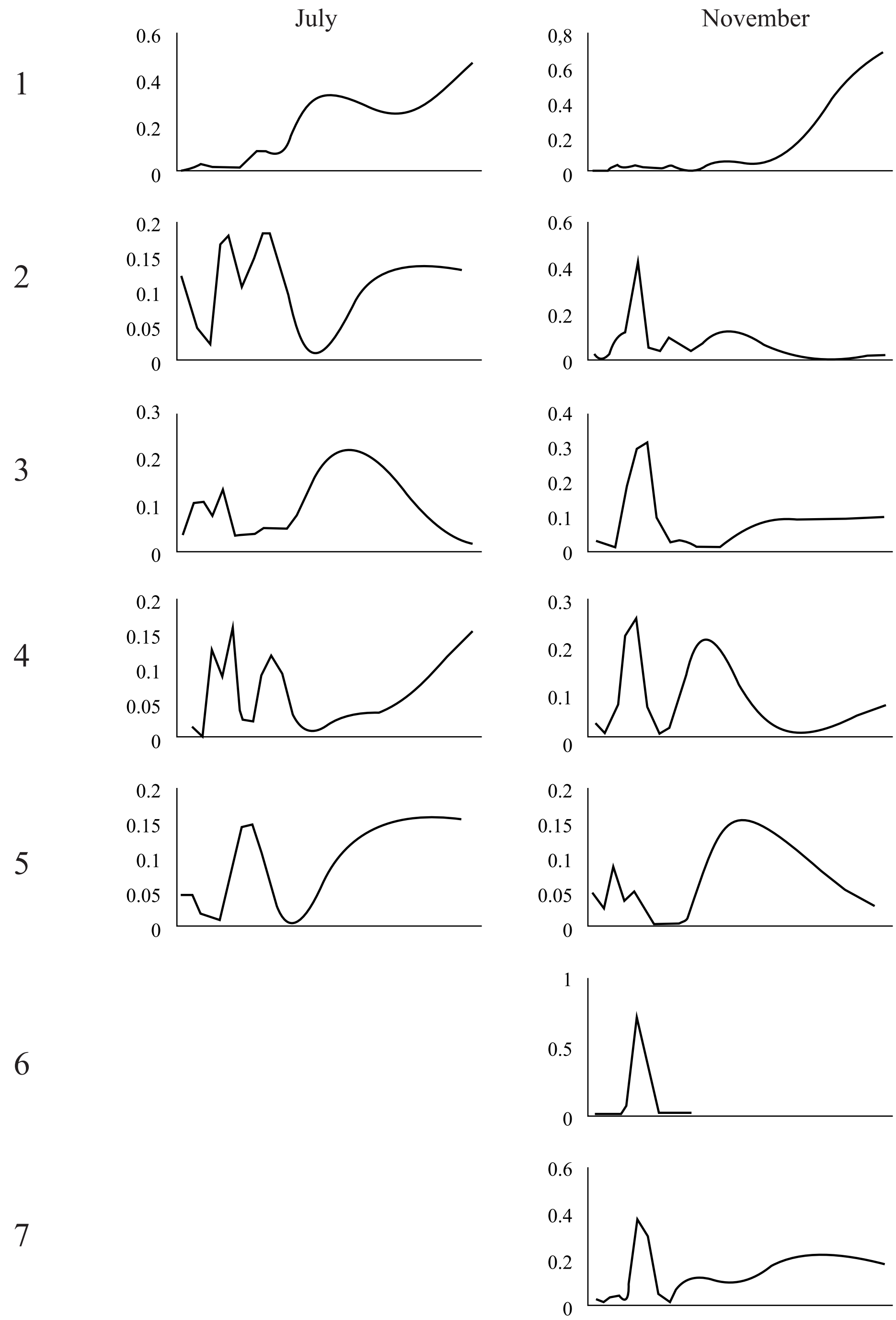

Figure 5. Periodograms for (a) July (left side) and (b) November (right side) showing the coefficient of determination for various periods in following activities or events (from top to bottom): 1) learning, 2) working or volunteering, 3) going out, 4) experienceing positive events, 5) experiencing negative events, 6) attending university and 7) completing other university-related assignemnts. Legends and text on charts were omitted due to insufficient space.

day of the study (the absolute number of participants taking part in the activity or experiencing a positive or negative event also could not have been used since the number of participants in the study was not the same each day). Single cosinor was then run on the percentage data for each activity or positive and negative event experience and the best

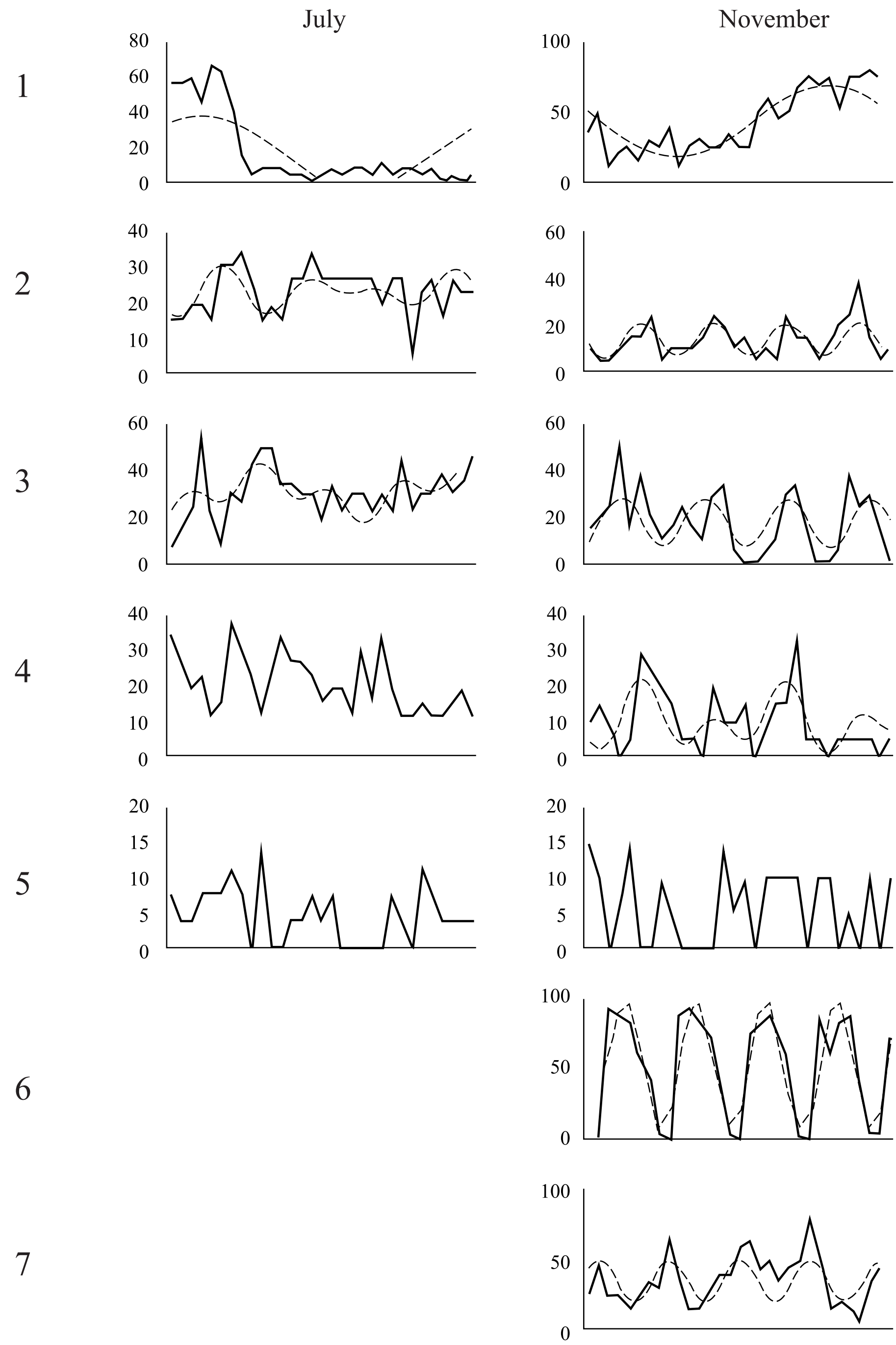

Figure 6. Percentage of participants in (a) July (left side) and (b) November (right side) taking part in following activities or events (from top to bottom): 1) learning, 2) working or volunteering, 3) going out, 4) experienceing positive events, 5) experiencing negative events, 6) attending university and 7) completing other university-related assignemnts. Continuous line shows empirical data and discontinuous line shows cosinor estimates. No significant rhythm was detected if no cosinor estimate is shown. Legends and text on charts were omitted due to insufficient space.

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Table 3
Best fitting period lengths (in days) for various daily activities in July and November

Daily activity	July	November
Learning	31	30
Working or volunteering	8, 12	7
Going out	7, 19	8
Positive events		7, 13
Negative events		
Attending university		7
Other university-related assignments		7

Note. Activities with two shown periods are best explained by a multi-component rhythm. No significant rhythm was detected in activities for which no period is shown. University attendance and completing other university-related assignments were not measured in July.

period for each activity or positive and negative event experience was again estimated by iterative cosinor procedure. Periodograms are shown in Figure 5 and period summaries in Table 3. Figure 6 shows the percentage of participants taking part in daily activities or experiencing a positive or negative event in July and November, and cosinor estimates (when possible).

To explore the relationship of mood and daily activities, correlations of the average mood rhythm and the percentage of participants taking part in an activity were calculated. It was found that the mood is positively correlated with going out in July and with going out and experiencing positive events in November, and negatively correlated with learning and experiencing negative events in July and learning and completing other university-related assignments in November (Table 4).

Table 4
Correlations of the average mood rhythm and participation in daily activities

Daily activity	July	November
Learning	-.538	-.551
Working or volunteering	ns	ns
Going out	.404	.465
Positive events	ns	.593
Negative events	-.431	ns
Attending university		ns
Other university-related obligations		-.478

Note. ns = not significant.

DISCUSSION

Neither of the two opposing hypotheses are fully supported by the results of this study. Both hypotheses predicted that the circaseptan mood rhythm would appear when the week was divided on the working week and the weekend, which is exactly what was observed in this study. However, both hypotheses failed to predict the 12-day mood rhythm, which was observed in the condition when the week was not divided on the working week and the weekend. The biological hypothesis predicted that the circaseptan rhythm of mood would appear regardless of the way the week is structured, since the rhythm is endogenous. In contrast with that hypothesis, the non-existence of a circaseptan mood rhythm in July should indicate that the rhythm is exogenous. This is in accordance with the viewpoint arguing that there are no natural zeitgebers marking the passing of the week that humans could synchronize to. In such a state, human mood is subject to cultural zeitgebers, which, when present, shape the rhythm of the mood in a 7-day cycle. Clearly, an alternate possibility is that the circaseptan rhythm of mood exists in July, but is less prominent and an another rhythm becomes dominant, which would be in accordance with the viewpoint that the circaseptan mood rhythm is endogenous, is also dismissed since a significant 7-day rhythm was not detected in July.

However, the cultural hypothesis predicted that no rhythm would appear in July, which is not what was observed in this research. A significant circasemilunar[1] rhythm with a period of 12 days appeared in July. There is no straightforward explanation as to what could have caused the 12-day rhythm of mood. Circasemilunar rhythms were mostly observed in reproduction rates of certain marine animals (Hsiao & Meier, 1992; Saigusa, 1988). The natural zeitgebers for those rhythms are believed to be the moonlight and the tidal variables (Naylor, 1985), but these variables are poor candidates for the zeitgeber which synchronizes the human mood to a 12-day rhythm. Most of human behavior is not dependent on marine tides, while lunar cycles are present throughout the whole year and we would therefore expect the circasemilunar cycle to also appear in November if it was due to moonlight, which it didn't. The variables which would be good candidates for a zeitgeber which synchronizes the mood to a circasemilunar cycle are either those that are not present in November but are present in July, or those that themselves undergo a change in period from circasemilunar to circaseptan rhythm.

Data on daily activities or positive and negative events of participants are of great interest in search for circasemi-

1 A rhythm with a period of approximately half a month, more precisely ~12.4 days (Matešić, 1983).

lunar zeitgeber candidates. In addition to Pearson's coefficient of correlation, periods of activities and events can be compared to the periods of mood. Two rhythms can have a similar period, but the correlation will turn out insignificant if their acrophases and amplitudes are not too similar or too different. Unfortunately, no variables that are present in July, but not in November, were measured, which means that the best currently obtainable candidate for a zeitgeber is a variable which has a circasemilunar rhythm in July and a circaseptan rhythm in November. One of the activities clearly stands out from the others fulfilling this criteria: work (Figure 5). While most activities or events displayed a circaseptan rhythm in November, work is the only variable that also displayed a circasemilunar rhythm of 11 days during July. It is possible that the mood rhythm was influenced by work in July. This is, in fact, just a variation of the previous cultural hypothesis because the cultural hypothesis predicted that mood will display no rhythmic variations in July, whilst assuming that variables which entertain mood to a 7-day rhythm are not present (e.g., university attendance) or are not rhythmic themselves. However, if those variables are rhythmic as demonstrated by this research, it is logical to assume that the mood will follow a similar rhythm. Thus, it seems that the ultralunar mood cycles are exogenous and greatly determined by recurring obligations such as work or university attendance.

It is important to point out that it cannot be said with full certainty that the 12-day mood cycle is determined by work for several reasons. Firstly, mood and work rates are not significantly correlated. If the work rates determine the duration of the mood cycle, according to the cultural hypothesis the correlation should be negative. However, the participants of this study reported jointly whether they were working or volunteering on each day, which possibly distorted the data since it can be expected that volunteering increases the mood, while working decreases the mood. Further studies should distinguish work and volunteering activities and their influences on mood should be studied separately. Secondly, it should be noted that the work rates display a multicomponent rhythm, while mood displays a single component rhythm. A significant single component circasemilunar rhythm of work rates was not detected. Thirdly, it is not known why work rates themselves display a circasemilunar rhythm. It is possible that the work rates do not influence mood at all, but that the same factors, which cause them to vary in a circasemilunar manner, also cause the mood to vary in a same manner. Further studies should be conducted in cases where work rates do not follow a circasemilunar rhythm to examine the rhythmicity of mood in these circumstances. Because work rates could display non-systematic rhythmicity, and mood rhythm could be influenced by work rate rhythm, it cannot be said with certainty that mood truly displays a circasemilunar rhythm during summer months. While findings on circaseptan mood rhythms have been replicated in several studies, this is the first instance of the finding of a circasemilunar mood cycle. Replication studies should be carried out before it can be said with certainty that a circasemilunar rhythm exists when the week is not clearly divided on the working week and the weekend. Furthermore, the sample studied in this research is mostly female. Since the sample size in this research is small, it is possible that the phases of the menstrual cycle were not distributed randomly throughout the month. The 12-day rhythmicity of mood observed in this research is similar to the rhythmicity of levels of estrogen, progesterone and follicle-stimulating hormone (Farage, Neill, & MacLean, 2009). It is possible that the 12-day rhythmicity of mood is under the influence of the menstrual cycle. To explore this possibility in the future, further research should also collect data on the phase of menstrual cycle from female participants. However, the possible influence of the menstrual cycle on the rhythmicity of mood does not undermine the basic finding of this study, which is that the structure of the week impacted the mood rhythm, making it circaseptan in the November and even possibly overrunning the rhythm influenced by the menstrual cycle.

The notion that the ultralunar mood cycles are determined by external societal factors can be further elaborated by looking at the proportion of explained variance in July and November. In the best case, 12-day rhythmicity accounts for 28% of the variance of mood in July, while 7-day rhythmicity accounts for 55% of the variance of mood in November. This difference can be explained with the influence of various activities on mood. As demonstrated in this study, only one of the activities or events displays a circasemilunar rhythm in July as a component of a multicomponent rhythm, and no activity or event displays a 'pure' circasemilunar rhythm. On the other hand, three activities or events display a 'pure' circaseptan rhythm in November, and one activity or event displays a circaseptan rhythm as a component of a multicomponent rhythm. Thus it is possible that the synchronization of the mood to a circaseptan rhythm in November is stronger than the synchronization of mood to a circasemilunar rhythm in July since there are more factors entertaining the mood to a circaseptan rhythm. Furthermore, the acrophase of the circaseptan mood rhythm occurs on Friday, or somewhere between Friday and Saturday if serial sections are used, while the bathyphase of the university attendance rates, which could be a primary determinant of the circaseptan mood rhythm, occurs on Saturday. Currently no non-societal factors are known to have their peaks or nadirs precisely on weekend, which also supports the hypothesis that the circaseptan mood rhythm is exogenous.

It is also worthy to note that in this research a significant 7-day or 12-day mood rhythms were only detected if the length of the analyzed timespan was longer than 7 or 12 days, respectively. Serial section analysis produced non-significant p-values if the interval length was the same as period length. This means that the intraperiod variations were

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too great for a significant rhythm to be detected, but with a longer timespan these variations become less pronounced than the underlying rhythm. This is likely due to small sample size. However, even with the interval length of 14 days, mood departs from a circaseptan rhythm at the first few intervals at the beginning of November. This can be observed on the chronogram (Figure 4b), where the empirical data and the cosinor estimate differ the most at the beginning of the month. It appears that there is a small peak of the mood at the beginning of the month before four large circaseptan peaks, which could account for the non-significant *p*-values. Given the fact that the classes started in mid-October, it is possible that the synchronization of the mood rhythm to the 7-day period was not yet finished when the November cycle of this study started and this small mood peak could be an indicator of the synchronization process. Further studies should be conducted to examine the variation of mood in times of transit, when the period of the mood rhythm changes (e.g., October, June).

Results of this research also indicate the possibility of a circalunar mood rhythm. Periodograms for both July and November (Figure 1) show the possible presence of a circalunar rhythm. Furthermore, lowest average mood was noted in the first few days of July (Figure 2) and near the end of November (Figure 3), which is when the moon was in the full moon phase. Although some meta-analyses (e.g., Rotton & Kelly, 1985) concluded that mood phases do not influence human behavior, it would be useful to analyze monthly mood data using a rhythmometric approach. Future research should explore this possibility and mood data should be taken during several subsequent months to eliminate intraperiod variations and allow for a clearer detection of circalunar rhythm.

It is also interesting to note that the MESOR of the mood rhythm was raising in July and falling in November, which indicates that the mood also has a circannual rhythm. Previous research has also documented this fact (Harris & Dawson-Hughes, 1993). Correspondingly, some aspects of behavior have also been shown to exhibit a circannual rhythm (e.g., suicide rates; Maes, Cosyns, Meltzer, De Meyer, & Peeters, 1993). Sources of those variations are not the subject of this study, but taking into account the fact that the sample in this study consists of students, one possible explanation for such variations of MESORs are exam dates. This study showed that the mood of students grows after the exams at the beginning of July are finished and, correspondingly, that their mood falls as the exams at the beginning of the December approach. Further research should be conducted on non-student samples to explore these variations. Besides exams, weather conditions are probably also an important factor impacting the growth and fall of MESORs. Over the course of evolutionary history, humans could have become adapted to these constant and predictable external variations, thus making the circannual rhythm endogenous. Previous studies have shown that weather can influence daily mood, although its effect varied greatly between individuals (Denissen, Butalid, Penke, & Van Aken, 2008).

Other cosinor parameters besides MESOR were also found to be non-stationary in both months during which this study was conducted. Amplitude variations followed an opposite trend compared to MESOR variations – amplitude was falling in July and growing in December. In studies of rhythmic variations, amplitude is considered to be a measure of rhythmic behavior of the measured variable. This is due to the fact that if the amplitude is zero, the rhythm does not exist, meaning that the measured variable is linear and not sinusoidal, which is observable from the equation for the cosinor model (Cornélissen, 2014). Some methods of period estimation (e.g., spectral analysis) use amplitude instead of the coefficient of determination to approximate the best period (Stoica & Moses, 2005). Also, serial section analysis of a multicomponent rhythm uses the amplitude as a measure of the prominence of each component during time (Cornélissen, 2014). Therefore, amplitude trends observed in this study show that the 12-day mood rhythm in July becomes less prominent as time passes and 7-day rhythm in November becomes more prominent as time passes. In accordance with this, mood rhythm in July seems to differ the most from the cosinor estimate at the end of the month, while mood rhythm in November differs the most from the cosinor estimate at the beginning of the month. While potential reasons for the differences between empirical data and cosinor estimates in November were already mentioned, potential reasons for these differences in July are unknown.

The acrophase was also found to be non-stationary in this research. In both months of this study, the acrophase value increased. It is difficult to say what could be the cause of this variation. Acrophase growth can be a sign that the period being analyzed is too long (Arbogast et al., 1983). However, no significant rhythms with shorter period than the best-fitting period were found in this research. Therefore, it is unknown what may have caused the acrophases in this research to grow.

Many conclusions of this research should be replicated before generalized.. One of the limitations of this research was a small sample size, which reduced the statistical power and possibly distorted the data. Furthermore, caution should be exercised while making population-level inferences about the rhythmicity of mood. Studies investigating circaseptan mood rhythms were mostly conducted on students, and this study has the same limitation. While it could be expected, based on the evidence from previous research, that other sub-populations (e.g., workers) also exhibit a circaseptan mood rhythm when the week is clearly divided in the working week and the weekend, this expectation should be empirically confirmed. However, students were a particularly good sample for the purpose of this research. While the typical length of the vacation for workers is one to three weeks, students can have as long as four months free of ob-

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ligations (if they successfully passed all exams on first trial). Using workers for this type of study would be very difficult because researchers should have to find workers that have vacations that are long enough for mood to desynchronize from the circaseptan rhythm. To support the hypothesis that the mood is synchronized according to cultural zeitgebers, studies should be carried out on sub-populations of people on whom these zeitgebers do not have an impact (or do in a lesser extent), for example, the unemployed, the retired, or pre-preschool children. Additionally, mood rhythms of people who do not work on weekends can be compared to mood rhythms of people who work on weekends (but also have two days free in a week). Eventual differences in phases in these populations would also be an indicator of cultural zeitgebers.

Another limitation of this study is the possibility that the experience of a significant life event could have drastically distorted the mood of participants, making their mood rhythm less sinusoidal, which could influence the results of this study. A possible remedy for this problem would be to exclude the data of participants who experienced a significant life event (either positive or negative). While data on experiencing significant life events that would make such an exclusions possible was collected in this study, these exclusions were not performed since most participants experienced a significant life event at some time during the research. Another possibility would be to exclude their data only on those days when they experienced a significant life event since cosinor analysis can handle missing data. However, this would make many participants fall short of the >85% criterion for inclusion in cosinor analysis, which would make the data from this research unanalyzable.

It would also be useful to analyze weekly mood data using other statistical procedures. Several other techniques can be applied to measure signals, such as spectral analysis and Fourier transformations. These analyses would be better in detecting the interaction of different periodicities composing a rhythm, which could be particularly useful to analyze confusing results, such as the detection of a 12-day rhythm in July. However, such analyses are more complex and the cosinor analysis applied to data collected in this research was sufficient to detect the disappearance of the circaseptan mood rhythm in the case when the week is unstructured (July), which was the aim of this study. Future studies which could aim to explain the rhythmicity of mood when the week is unstructured should perform more complex analyses, such as spectral analysis, to better explain the interaction between different periodicities.

However, this study could have certain implications. Firstly, it is possible that other variables which exhibit a circaseptan rhythm only exhibit such rhythm when the week is ‘structured’. These results show that the measurement time is an important factor determining the period of the analyzed variable. It is known that the physiological variables can be under influence of the psychological variables, meaning that it is possible that the stress levels influenced physiological variables which exhibited a circaseptan rhythm, thus also making their rhythm circaseptan. This possibility must be assessed and if true, clinical practitioners could change their treatment methods accordingly.

The second implication of this research is based on the notion that mood rhythms can be artificially induced if the obligation schedule is changed, as was shown in this research. Many researchers found that the present structure of the week is not good for mental health (Ryan, Bernstein, & Brown, 2010). The possible reason for this finding is that the exchanges of elevated and decreased mood occur too fast, making all persons ‘passengers on the weekly emotional rollercoaster’ and deteriorating their mental health. Two things could be done to address this problem. Firstly, the duration of a week could be increased, however, such a transition would be too complicated and would probably have many economic and other implications. Such a transition would require the whole calendar structure to change. However, the duration of the working week could be shortened, while keeping the duration of the full week intact. This would slow down the exchange of peaks and nadirs of mood, probably lowering the amplitude of the mood rhythm. While this solution is not without its disadvantages, the transition to a 4-day working week is not impossible and would have many positive effects. Some studies have already reported on the benefits of long weekends (Facer & Wadsworth, 2010). Transition to a 4-day working week could make the affective difficulties less frequent.

Conclusion

The structure of the week has an impact on the rhythmicity of mood. In the case when week was divided on the working week and the weekend, mood displayed a circaseptan rhythm. In the case when the distinction between the working week and the weekend was non-existent or less prominent, the mood displayed a circasemilunar rhythm. The most probable source of variations in rhythmicity are the recurring obligations related to university attendance and work. However, further studies should be conducted to support this notion.

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